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Approved for Release

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Creating a Secure Future for Nuclear Energy:

The Advanced Fuel Cycle Initiative

Los Alamos National Laboratory
Argonne National Laboratory
Idaho National Engineering and Environmental Lab
Oak Ridge National Laboratory

Presented by M. Cappiello
Los Alamos National Laboratory

February 2004

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AFCI Supports National and Global Needs

Imperative: Clean Sources of Energy are Needed Now

¥Carbon emissions are causing an environmental crisis.

¥Global demand for energy is increasing.

¥National energy sources needed for security.

Solution: Energy Production with non-carbon emitting technologies

¥Clean Coal

¥Nuclear

¥Renewables

But there are Challenges if Nuclear is to Grow:

¥New national repositories needed for spent fuel.

¥New approaches to global nuclear materials management needed to counter proliferation

AFCI is Part of the Solution:

¥ Close the fuel cycle without increasing proliferation risk.

¥Eliminate need for second repository.

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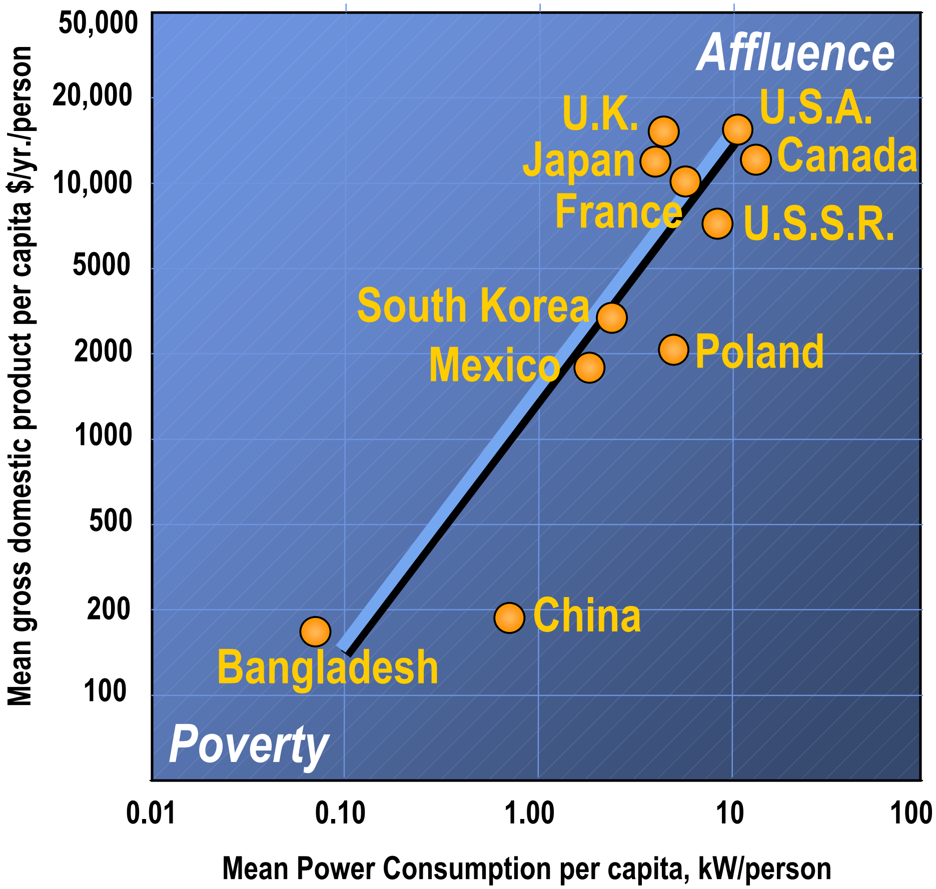
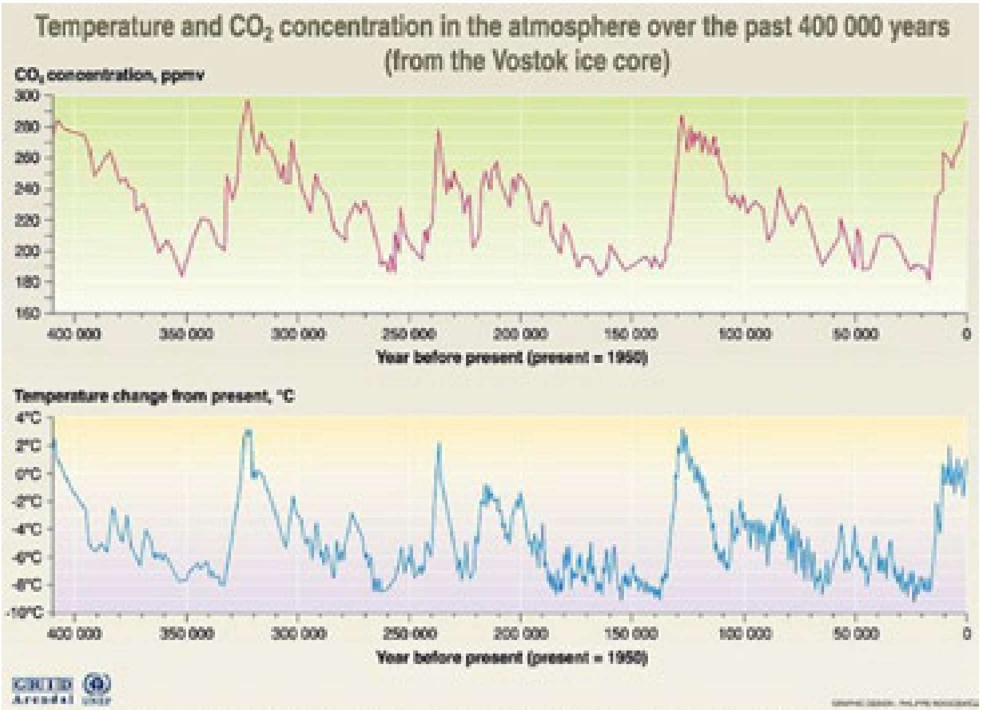
Imperative: *Energy use will grow as developing countries achieve affluence*

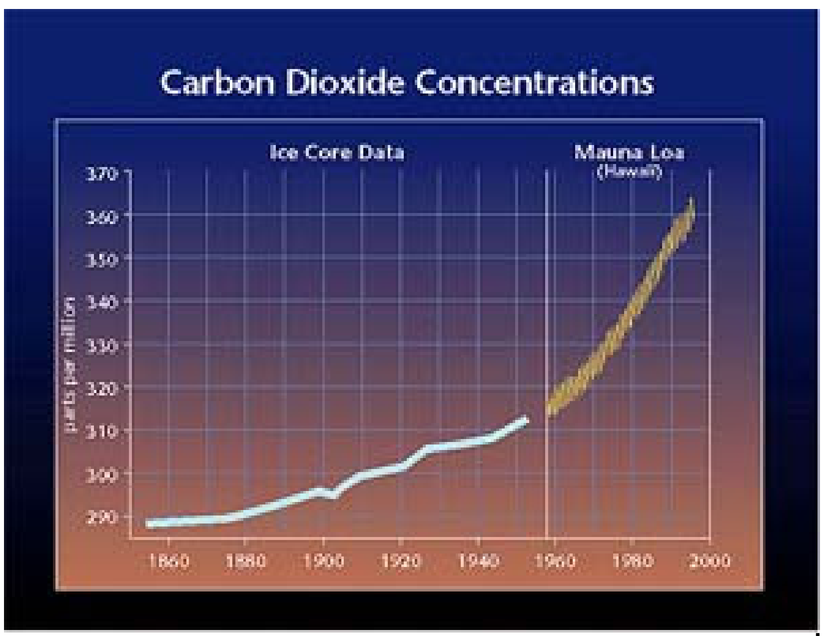


A world of 10 billion people consuming energy as U.S. citizens do today would raise world energy demand 10-fold.

Watts, Robert G. *Engineering Response to Global Climate Change: Planning a Research and Development Agenda.* Boca Raton, FL: CRC Lewis Publishers, 1997. QC981.8 .C5 E56 1997 GEO-MAP



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3June), pp 429-436, 1999.



Imperative:

Carbon Emissions are having a detrimental effect on our environment

- Current CO_2 levels approaching 380 ppm are unprecedented.
- Levels of CO_2 tolerance estimates are between 450–750 ppm.
- We are quickly approaching an environmental "Carbon Wall" crisis.

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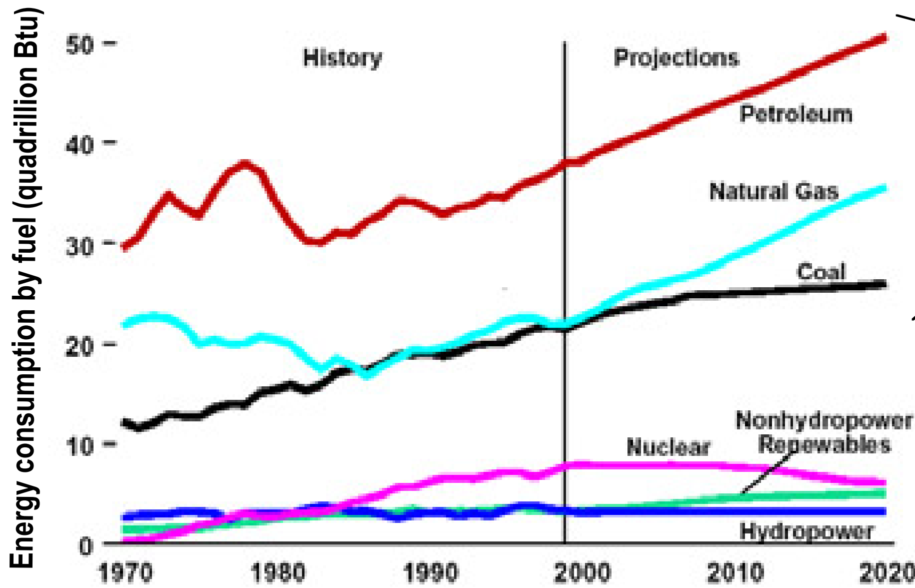
Solution: *Transition to **non-carbon** producing technologies*



This trend in fossil use needs to be reversed to avoid serious effects on the environment

The solution is to develop an energy production portfolio that minimizes carbon emissions:

- ***Clean Coal***
- ***Nuclear***
- ***Renewables***

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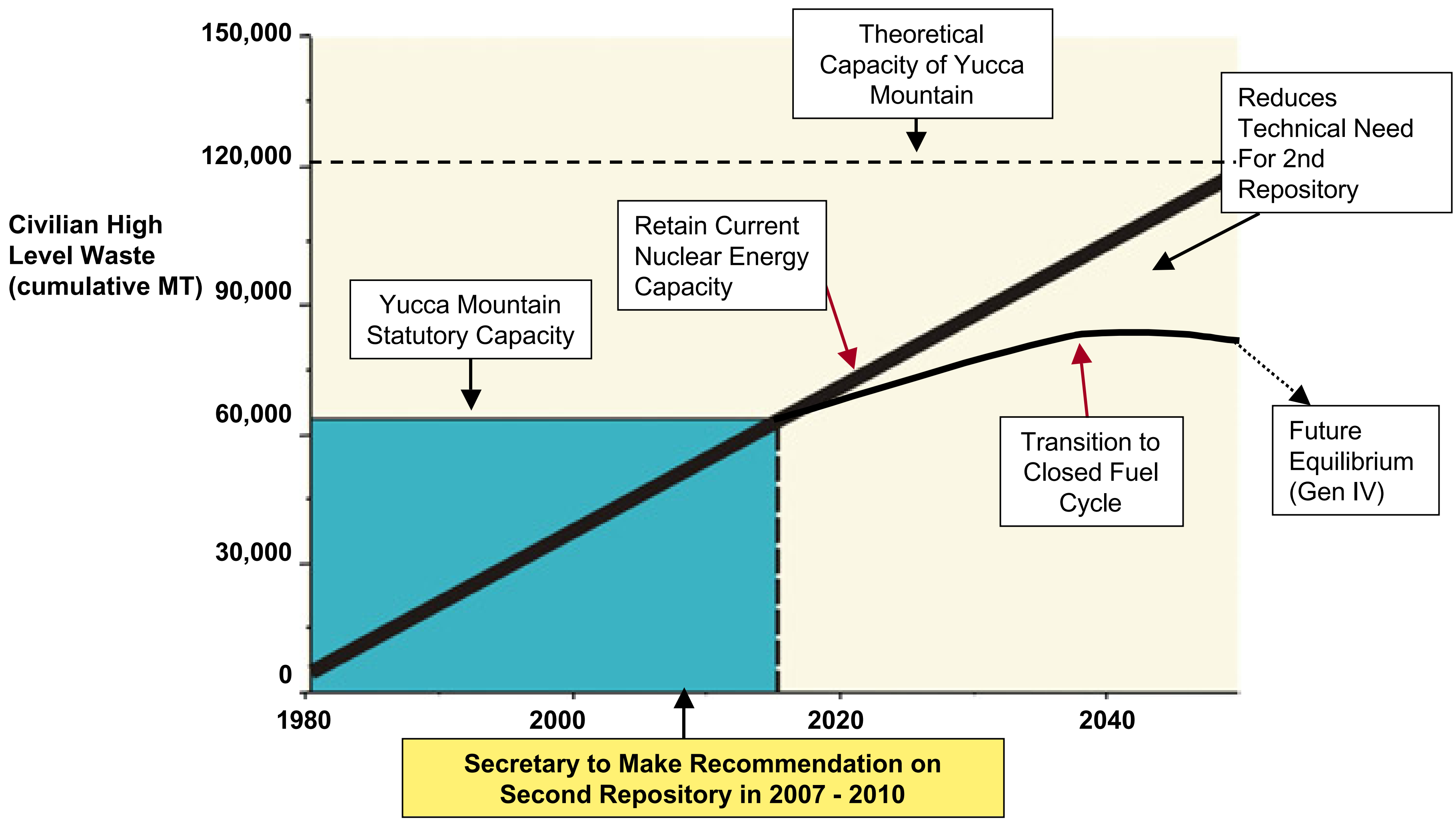
Challenge: Yucca Mtn. will reach its statutory limit in 2015. Alternative needed to second repository.



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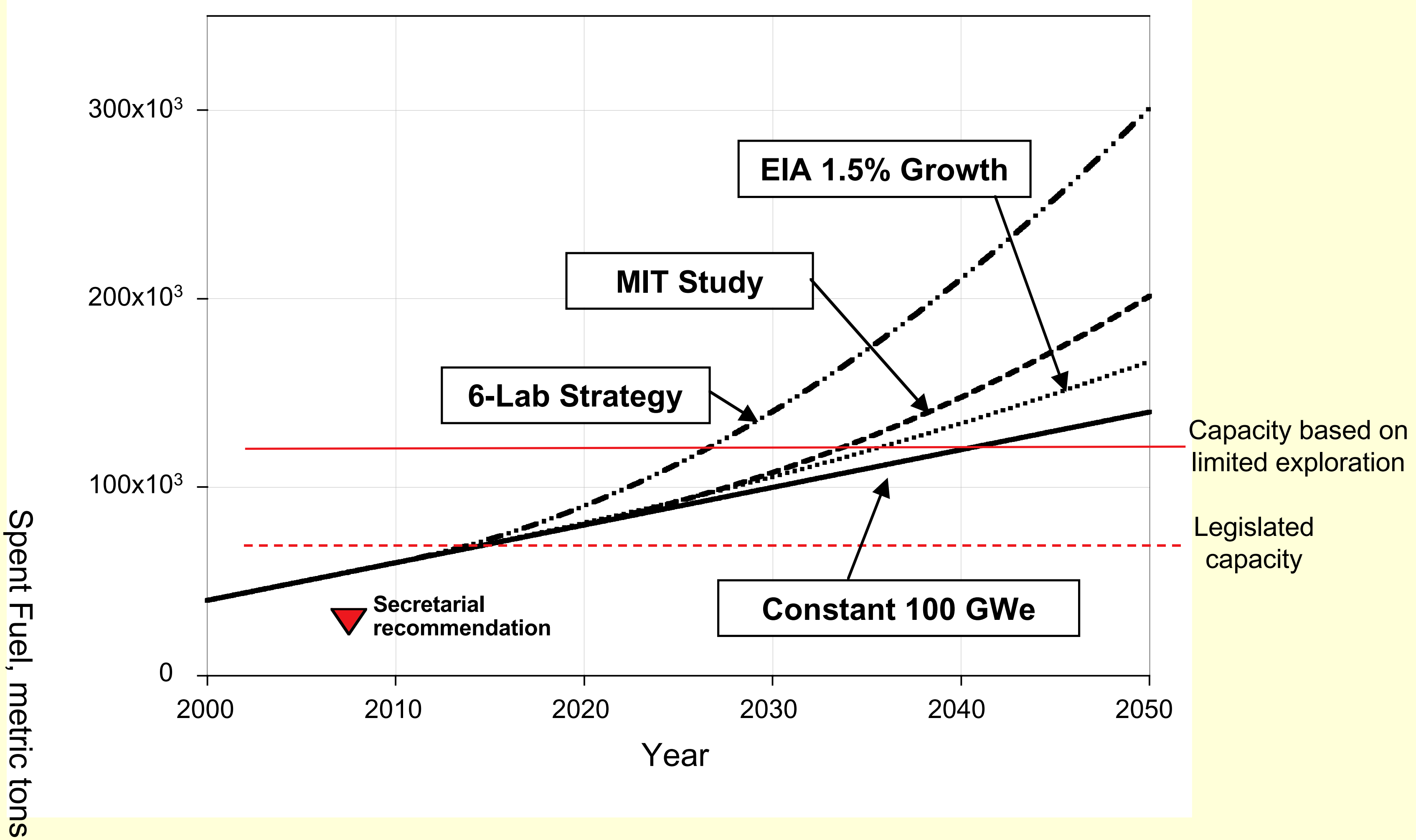
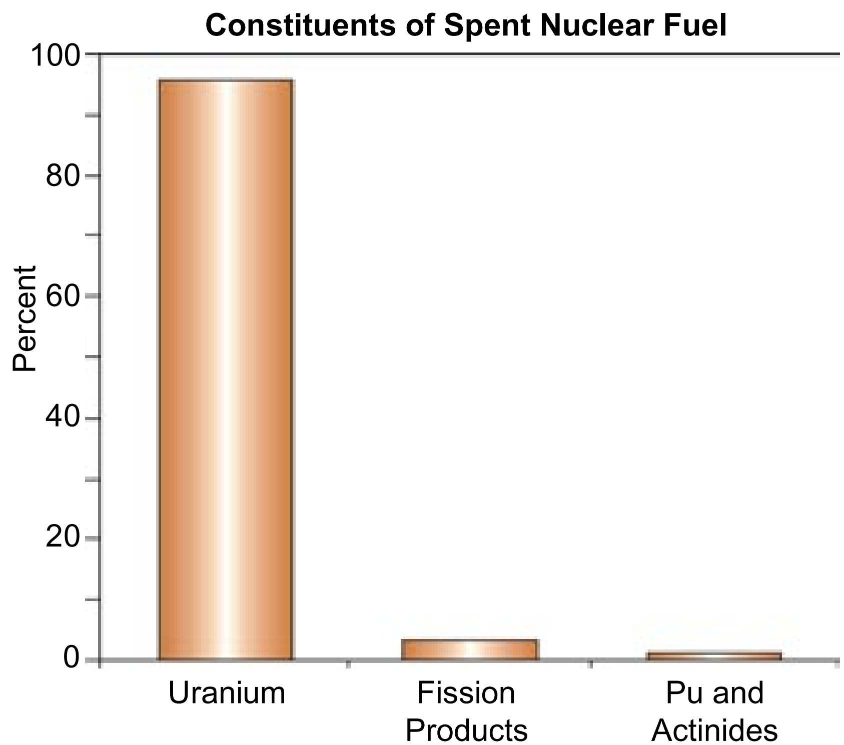
A new YM is needed every 30 years assuming constant 100 GWe, much sooner if nuclear energy grows



A small fraction of spent fuel dominates the disposal issues



95.6% is uranium -- can be dispositioned as Class C low-level waste or recycled

3% is stable or short-lived fission products that do not pose major disposal challenges

0.3% is cesium and strontium that decays in a few centuries (and are the primary near-term HLW heat source)

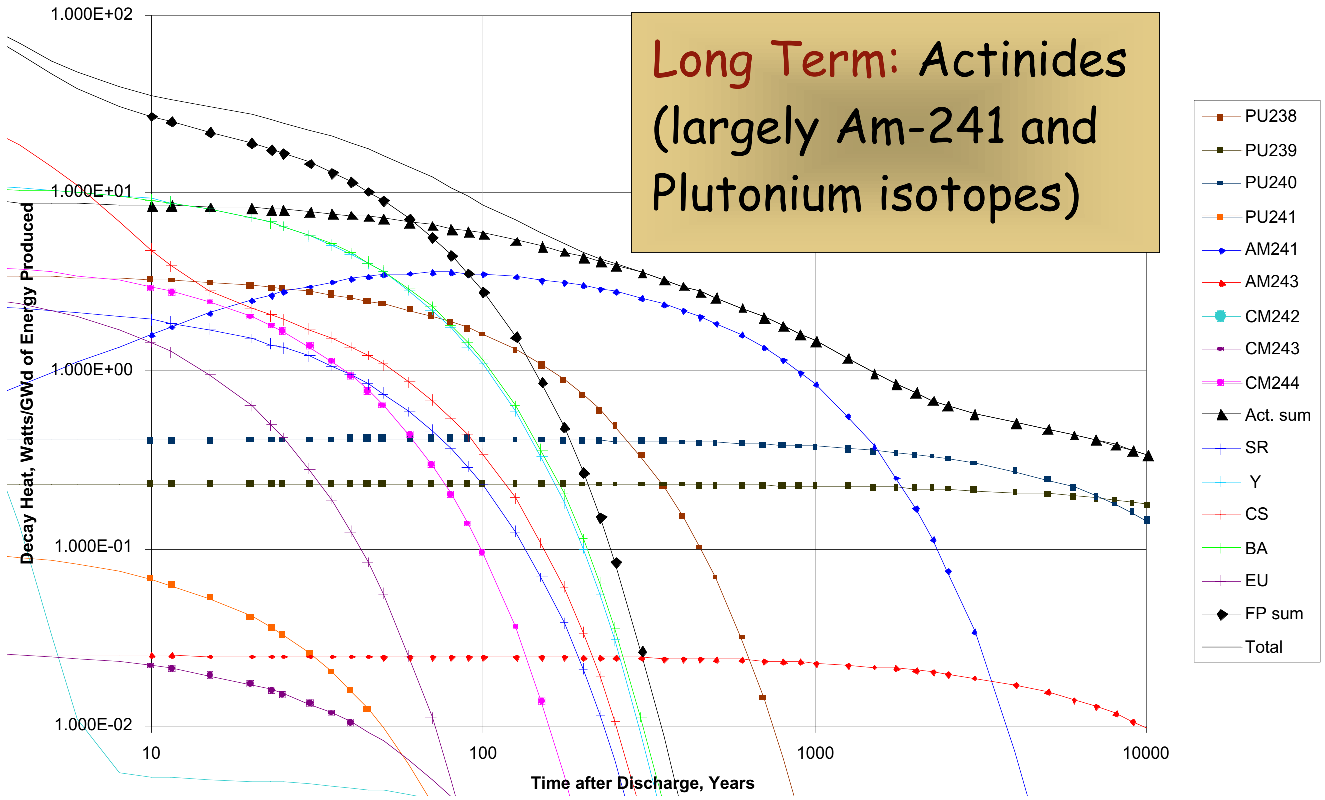
0.1% is long-lived iodine and technetium which can be transmuted

0.9% is plutonium which can be burned as fuel

0.1% is long-lived actinides which can be fissioned in fast spectrum reactors or accelerator-driven systems (ADS)

AFCI has demonstrated removal of uranium from actual spent fuel at a purity of greater than 99.99 percent.

Therefore AFCI is focusing on specific isotopes



Long Term: Actinides (largely Am-241 and Plutonium isotopes)

Short Term: Fission Products (largely Cs, Sr), decay in 300 years

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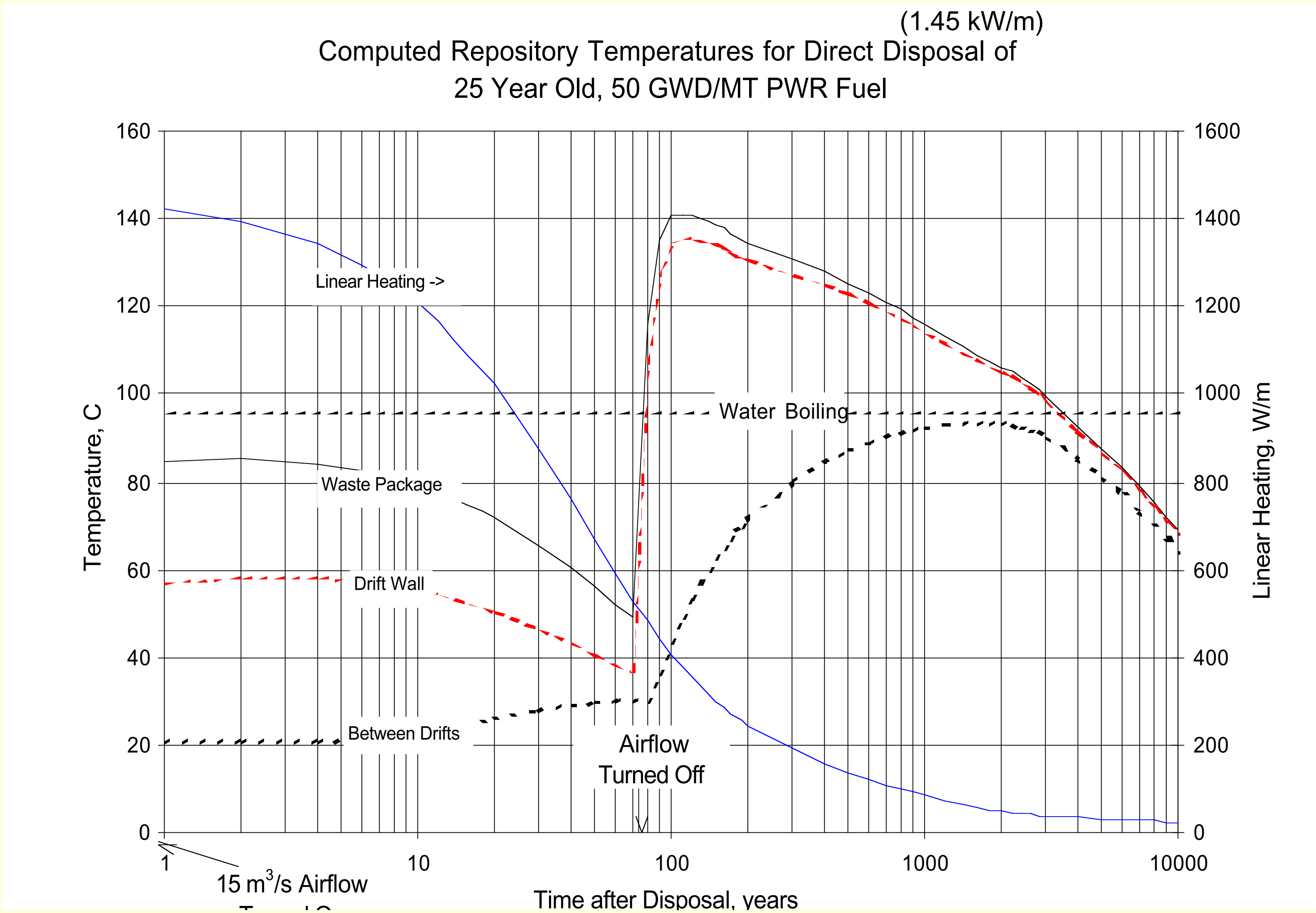
Repository Transient Thermal Response Determines the Capacity



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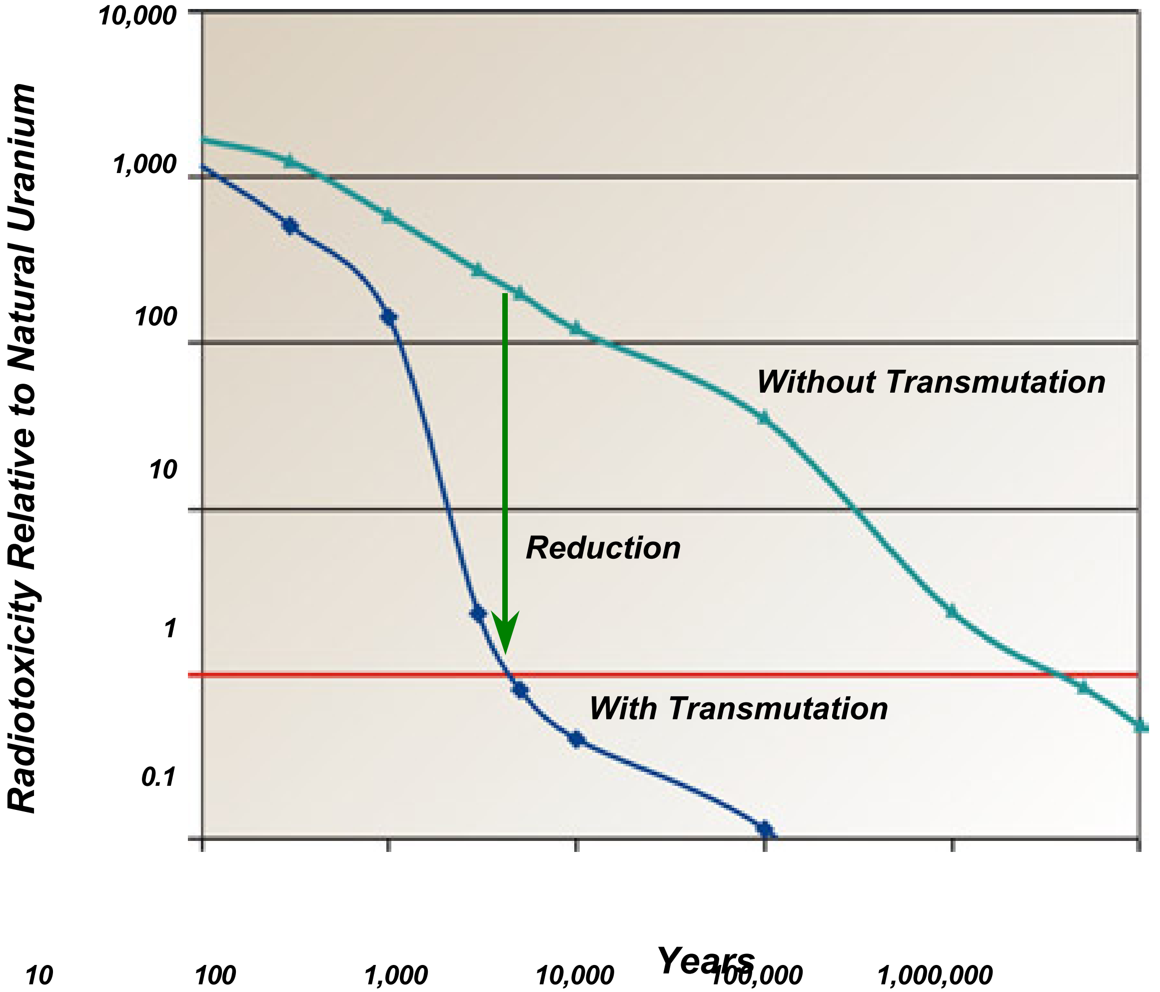
Removing and Transmuting the Plutonium and Higher Actinides also Provides a Major Reduction in Radiotoxicity



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Repository Capacity can be Increased Dramatically

Processing	TRU Recovery Efficiency		
	90%	*99%*	*99.9%*
Pu, Am removal only	2.1X	3.2X	3.4X
Pu, Am, Cs, Sr removal	3.0X	20X	59X

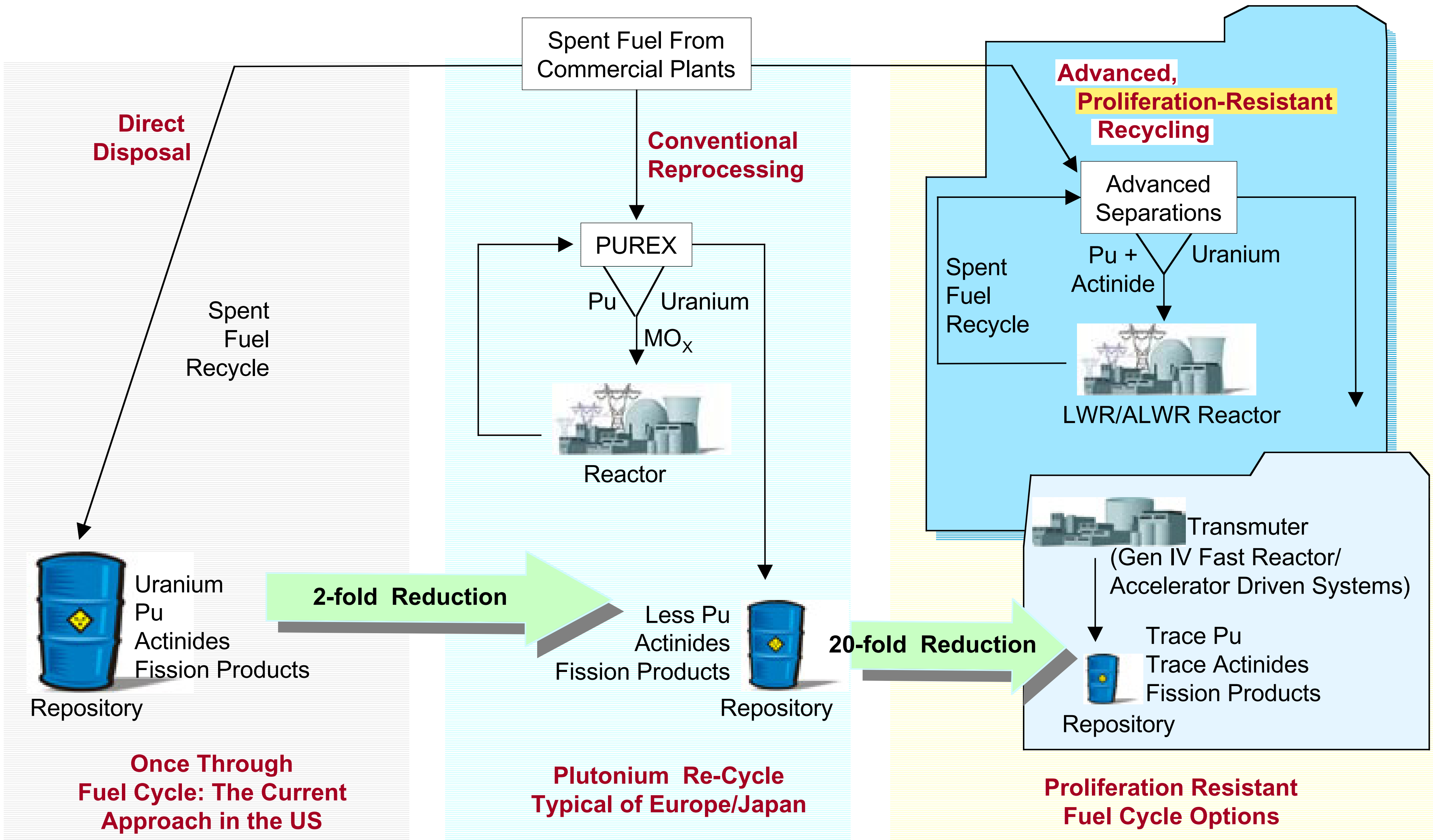
Goal is to achieve this kind of capacity increase, and make YM the last repository we need

Cost are reasonable when the savings on the repository are factored in

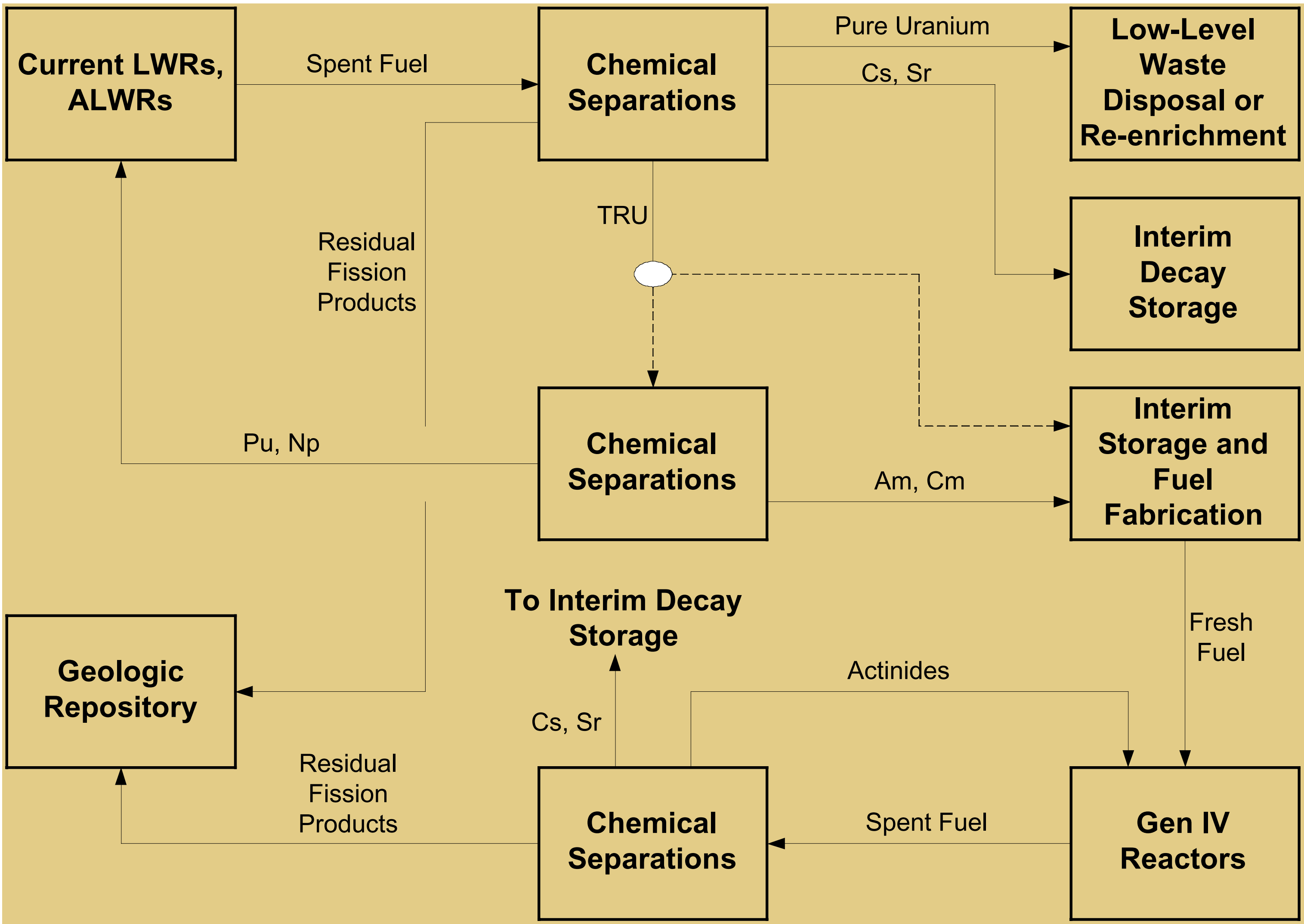
Item	Once Thru	PUREX	UREX	ACP/UREX
Development	4		2	2.5
Treatment		8	6	4
Fuel Fab		2	2	2
Repository	46			
Ops		20	14	12.5
Interim Storage		1	1	1
D&D		3	2.4	1.8
LWR Credits		(12)	(12)	(12)
Total (25yr)	50	22	15.4	11.8

Ref: AFCI Comparison Report, FY2003 (See DOE Website)

We are in the Process of Analyzing the Scenario Options To Achieve the Goals



Our Baseline for Future Nuclear Energy System Combines Separations, Storage and Transmutation



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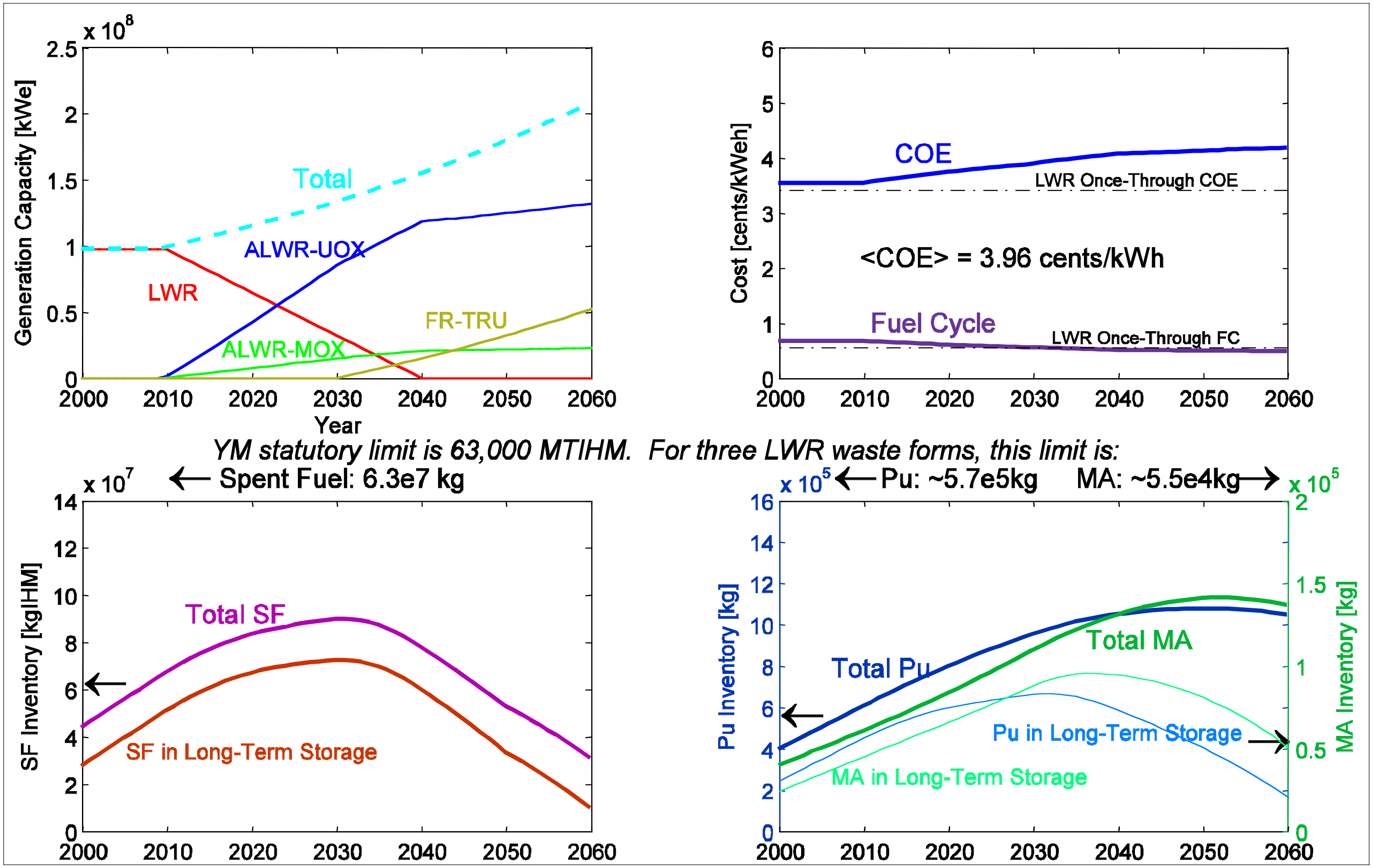
Our detailed system analysis code (AFCSIM) is being used to evaluate cycle scenarios. Example: 1.5% Growth, MOX recycle and FR



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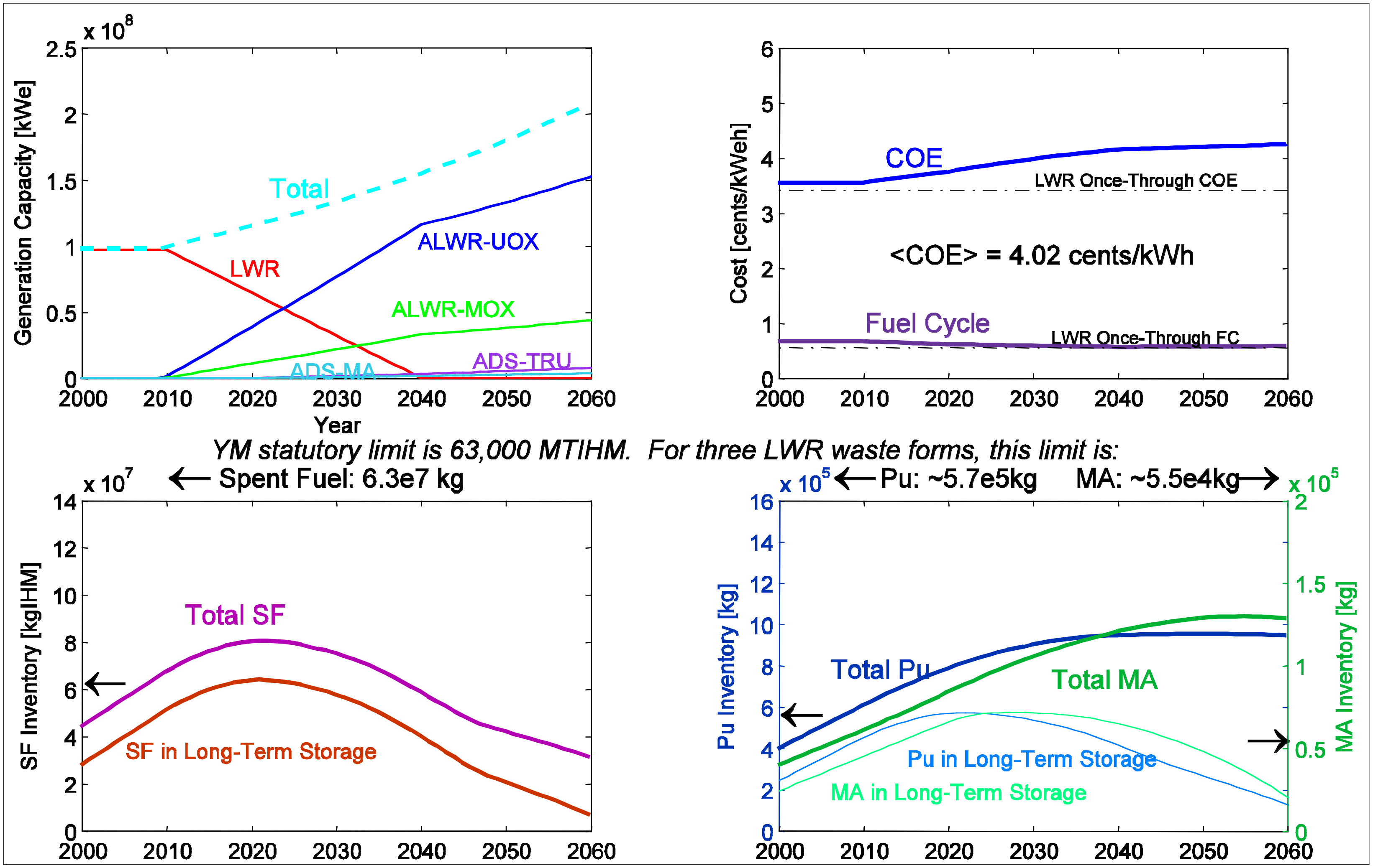
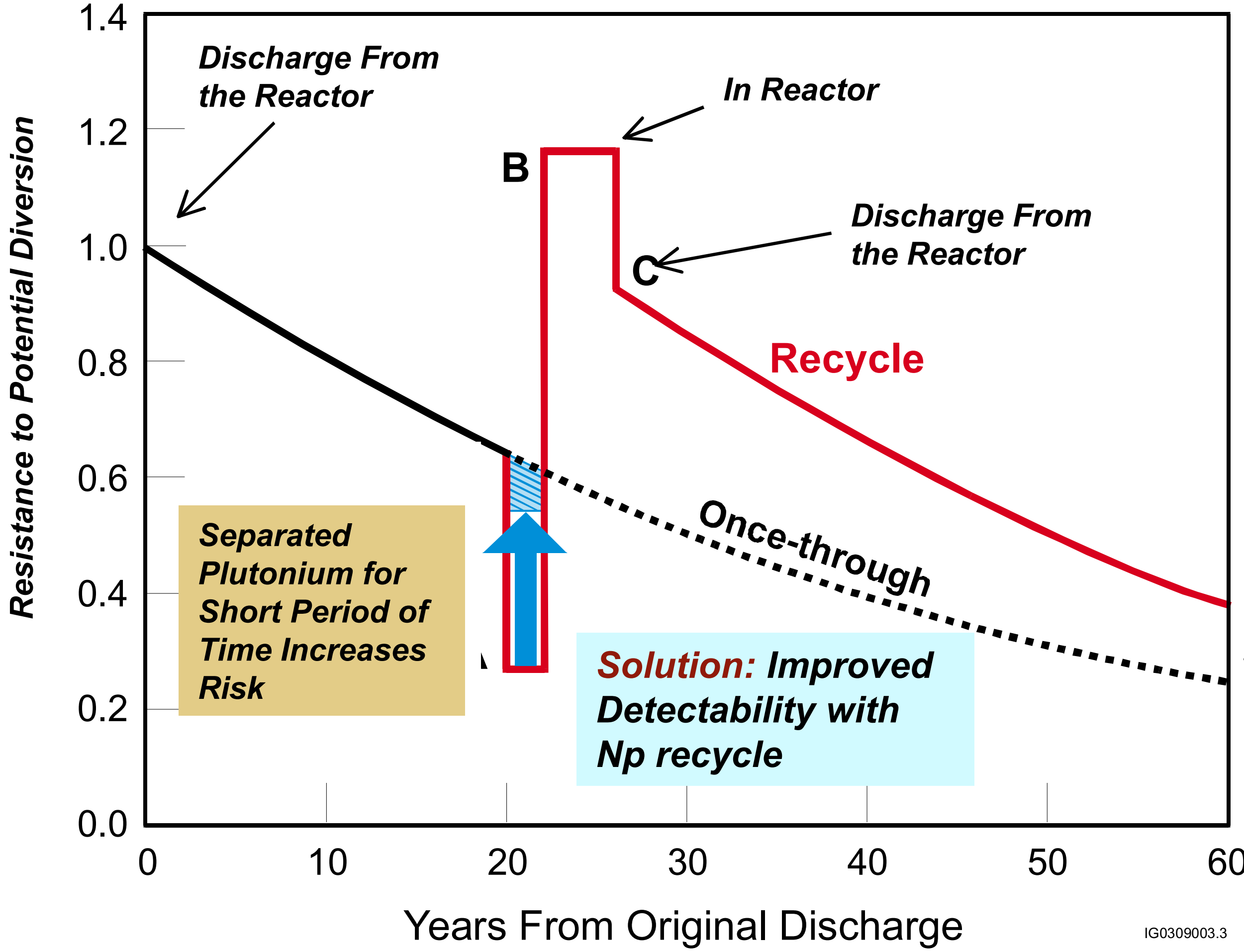
Example: 1.5% Growth, MOX recycle and ADS provide similar results



But the Closed Fuel Cycle Debate Continues (in the US)

CRITICS	***AFCI***
• Proliferation: Recycle produces separated Plutonium • Cost: Recycle will double cost of electricity	• Proliferation: Recycle destroys Plutonium, an AFC can reduce diversion risk • Cost: COE increase is ~10% when cost of SNF disposal is included

Challenge: ***Worldwide we generate 7Kg of Plutonium per hour. Plutonium is separated during recycle, therefore increasing the risk of diversion.***



***Solution:* Multiple Recycle or Deep Burn with IMF will destroy the Pu, and keep the resistance high**

For the once-thru cycle, the radiation barrier decays to 1R/hr, 1m after 110 years

Provider and User States to help manage nuclear materials globally

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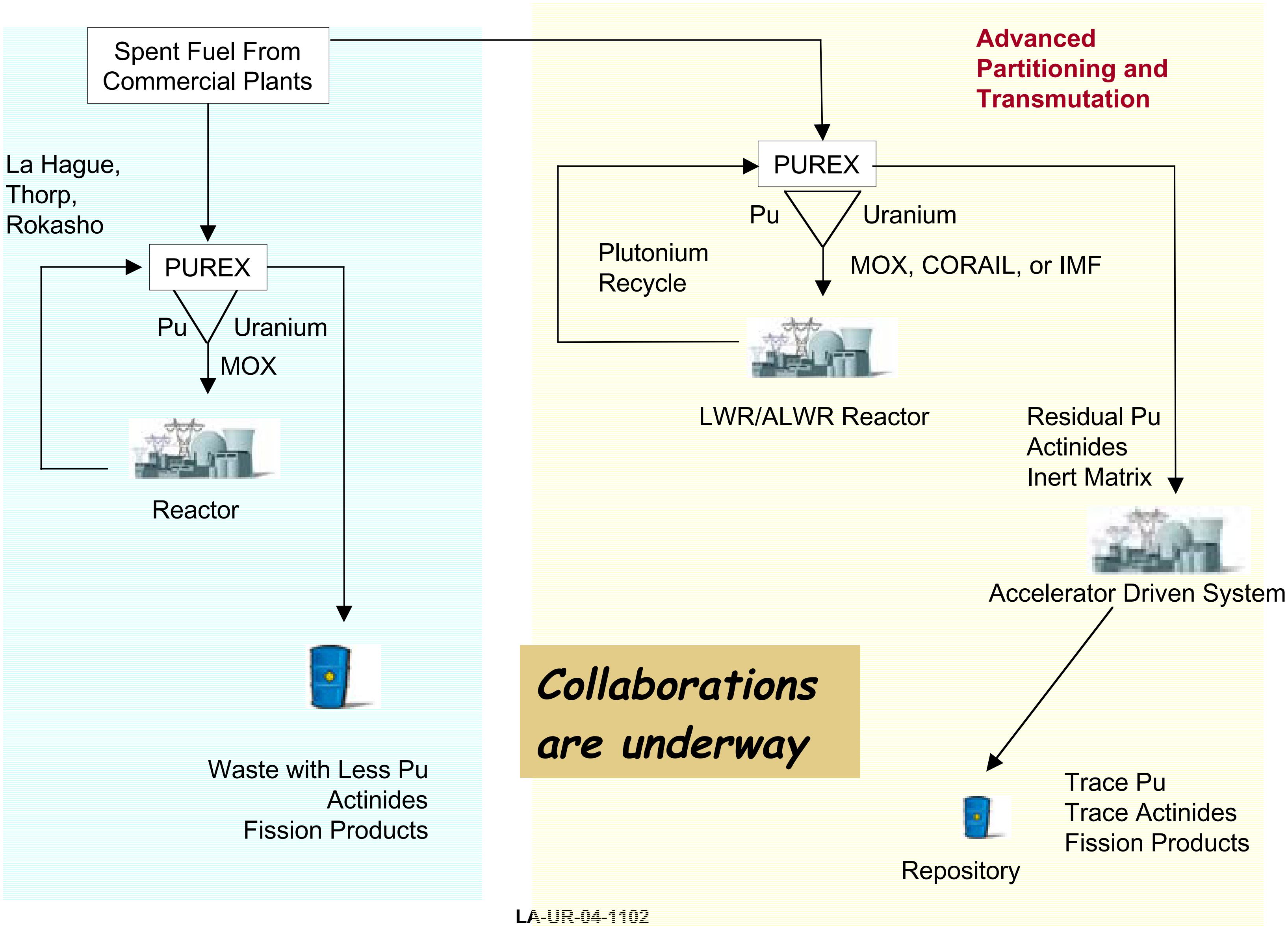
Special Note: Europe and Japan are way ahead.



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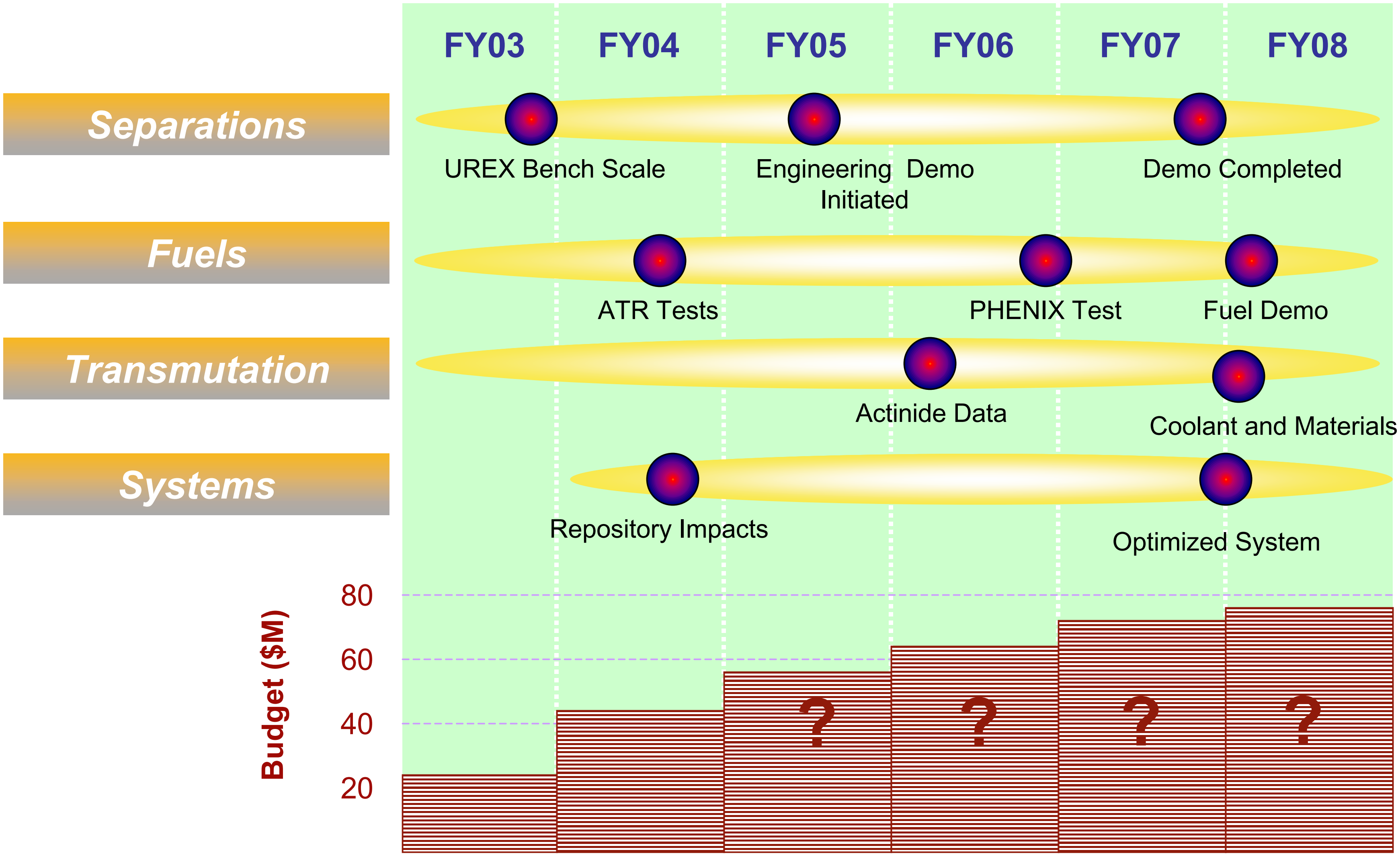
Five-Year Target: Demonstrate Alternatives to Second Repository for Secretarial Decision



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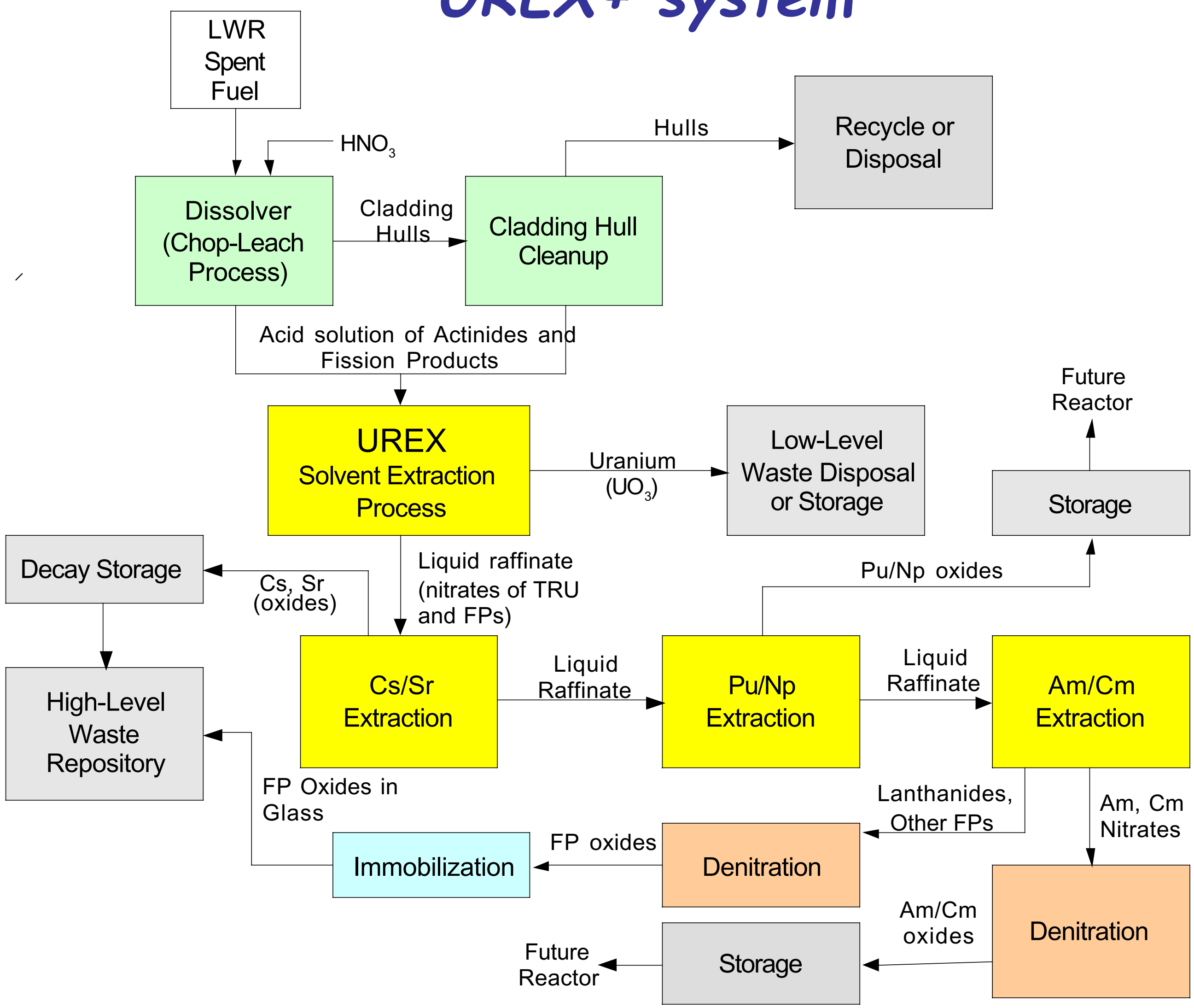
AFCI Technology Development is Preparing for the Secretarial Decision and Beyond

- Systems Analysis: Spent Fuel Treatment Options, Transmutation Options, Repository Impacts, Cost, Proliferation
- Separations: UREX+, Pyro-Chemical, Advanced Crystallization
- Thermal Spectrum Fuels: MOX, CORAIL, Inert Matrix
- Fast Spectrum Fuels: Oxide, Nitride, Fertile and Non-Fertile
- Transmutation: Nuclear Data, Coolant and Materials Technology

Our baseline treatment process is the aqueous UREX+ system



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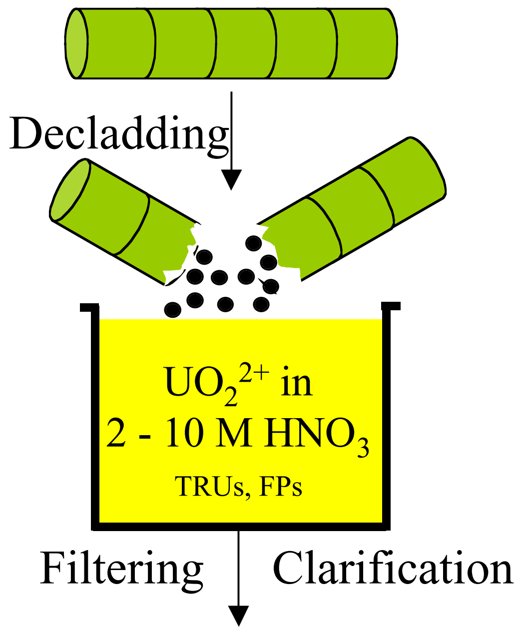
An option to the UREX solvent extraction is the Actinide Crystallization Process



Spent Fuel Rod

- Several stages may be needed to obtain required decon factors
- Uranium can be partitioned alone (Np and Pu with fission products)

Dissolver Tank

- Np(VI) and Pu(VI) will co-crystallize with U(VI) under oxidizing conditions (Pu(VI))

Crystallizer

Cooling to -20 to -40 C
or
Evaporative Concentration
with Washings
DF ~ 100

Solid → DF ~50 → DF ~25 → DF ~10 →

Uranyl Nitrate
DF 10^6

→ Filtrate to further separation processes

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Results are very encouraging

Bench Scale Tests Complete

Loop Crystallizer Operating

Hot tests to be performed this year with U, mg amounts of Np and Pu

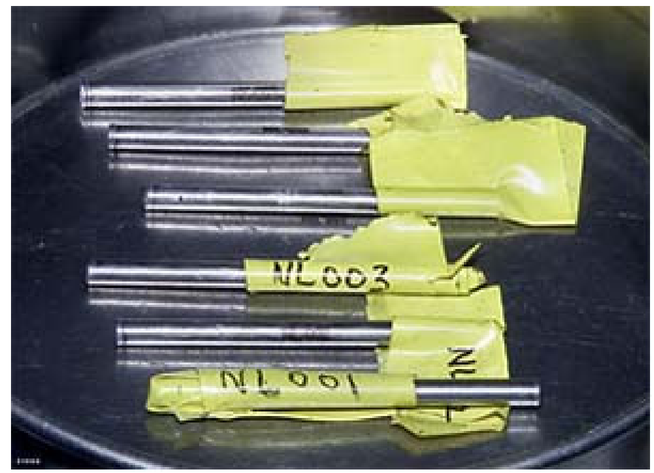
Both fertile and non-fertile actinide nitride pellets are being fabricated for irradiation testing

Production of Comp 5 ($(Pu_{0.5}, Am_{0.25}, Np_{0.25})N$-36ZrN) pellets sintered at 1650°C

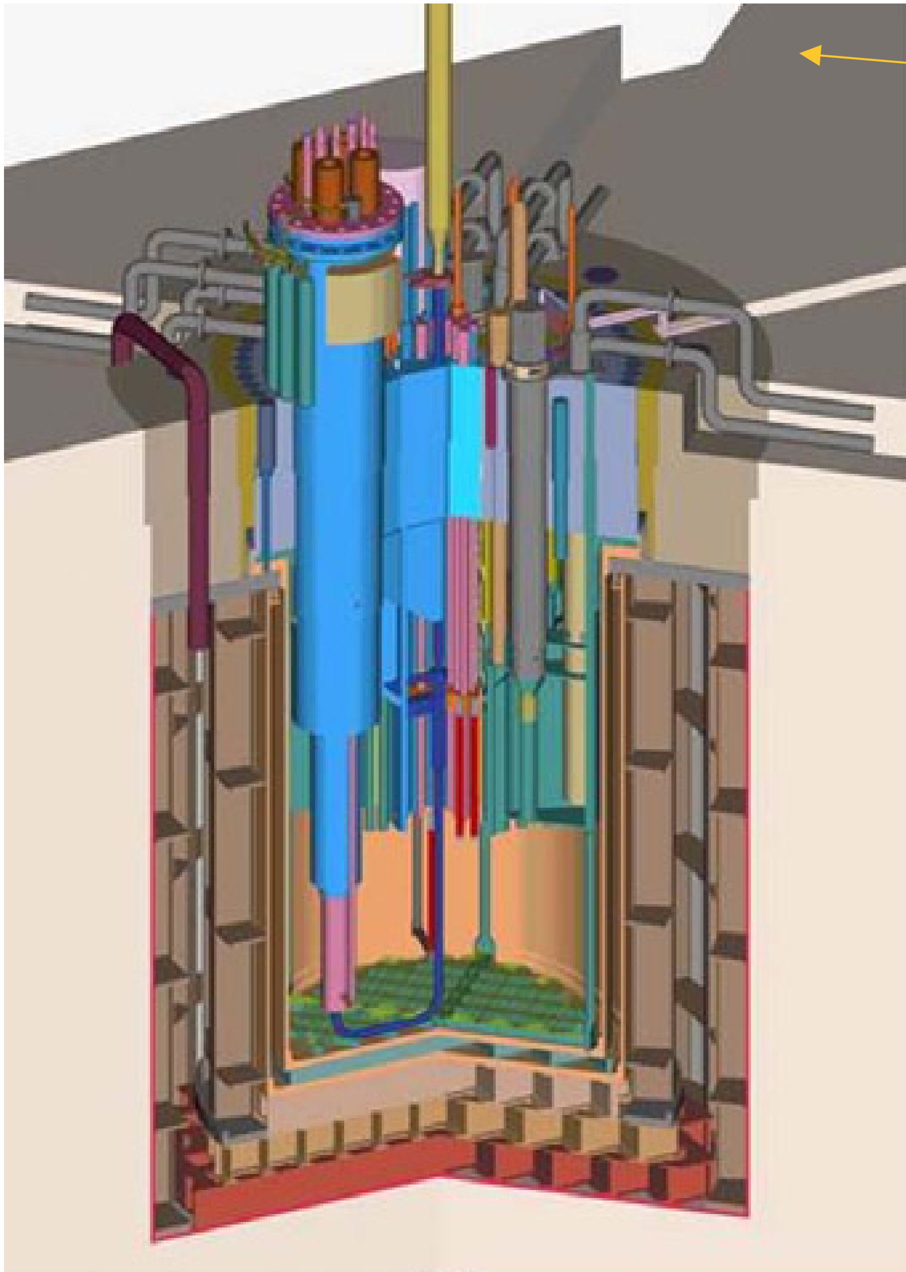
Production of Comp 4 PuN-36ZrN pellets sintered at 1700°C

These pins have recently been inserted into ATR

Assembly of nitride pellets into shipping vessel



Six shipping vessels with two compositions awaiting welding



ADS Design and Testing is being performed in Europe and Japan. The US provides target and accelerator technology support. An ADS can safely burn non-fertile actinides.

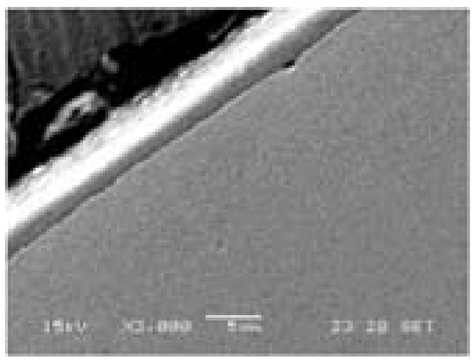
100MW XADS Design

Lead Alloy Coolant Technology: Application to both the ADS Transmuter and the GenIV Fast Spectrum Reactor

Recent Visit by Bill Magwood

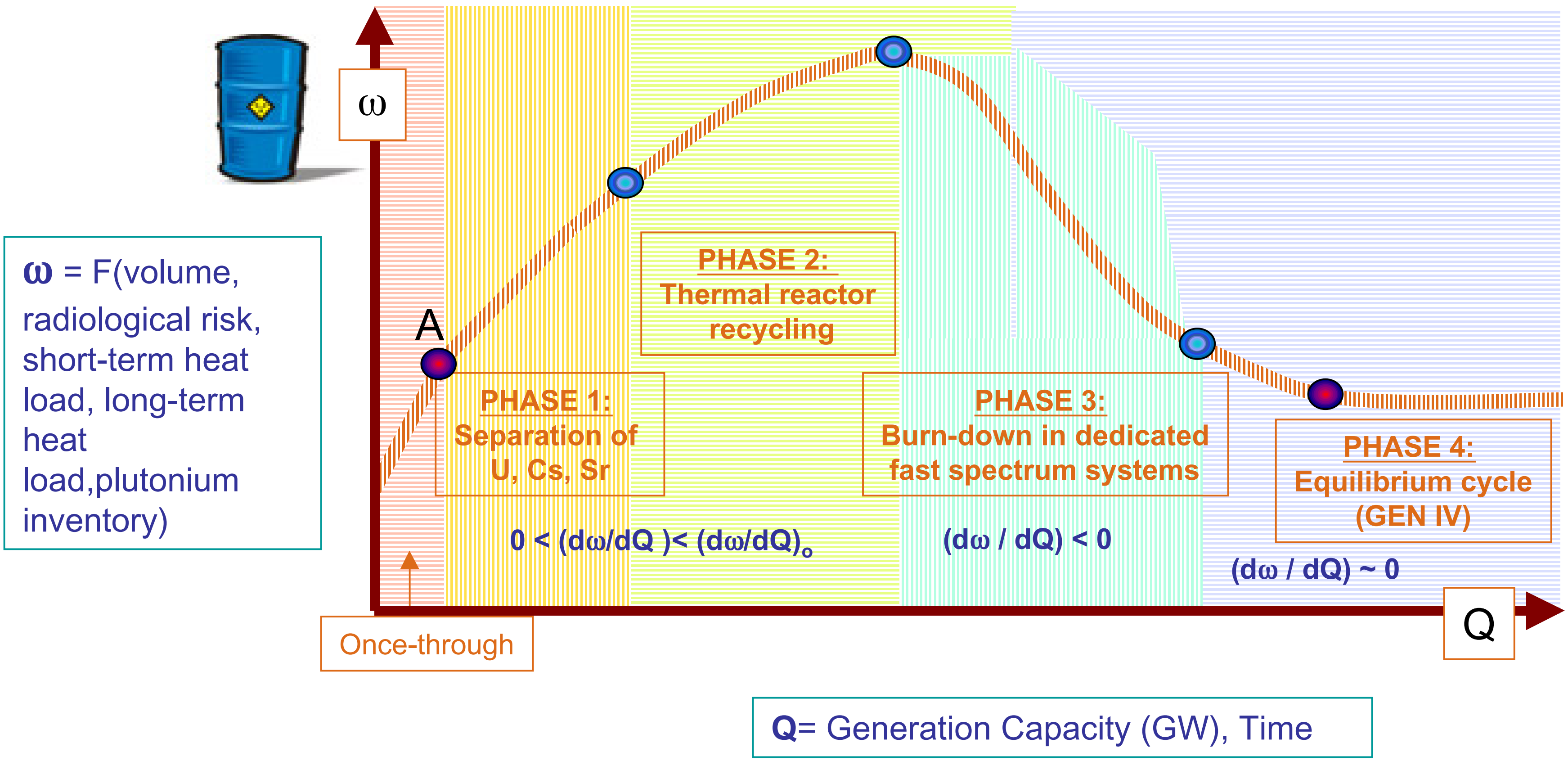
DELTA Loop

Oxide Layer Research to Minimize Corrosion



Lead Alloys can operate up to 650C. Technology based on 150 Reactor Years of operation in FSU.

If implemented, the AFCI provides the means to transition to a minimum waste producing fuel cycle and enable the continued growth in nuclear energy



Summary

- Why:
  - The AFCI enables growth in Nuclear Energy.
- What's the Imperative:
  - The "Carbon Wall" is quickly approaching, we need nuclear as part of the future energy portfolio.
  - More Yucca Mountains are needed starting in FY2015.
  - A new approach to Global Nuclear Materials Management is needed.
- What is it: Development of the technologies
  - Spent Fuel Treatment to partition uranium, fission products, actinides.
  - Recycle plutonium and neptunium in thermal reactors.
  - Burn residual actinides in fast spectrum systems.
  - Transition to Gen IV.
  - Reduce proliferation risk